Enhancing MPA Effectiveness: Identification and assessment of reproductively active serranid movement and fishery vulnerability

General Coral Reef Conservation: Marine Protected Areas and Associated Management Activities; Coral Reef Fisheries Management

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Executive Summary

A total of 647 squaretail coralgrouper, *Plectropomus areolatus*, were tagged within the Kehpara Marine Sanctuary (KMS) using conventional spaghetti-type Floy tags between 25 January and 25 May 2005. Included within this total are 22 males and 21 females implanted with Vemco V16® acoustic tags. Fifty-nine conventionally tagged fish (9.1% of the total) were recaptured over 15 months, with 38 (64.4%) of those taken within the spawning season (January-May). The latter total includes 20 fish recaptured within the KMS by taggers and 18 by fishers outside the sanctuary. Of the fish taken outside the sanctuary, five were from unknown locations, while 82% were captured within 10-12 km of the KMS, including 25 of 39 fish taken from channels immediately adjacent to the spawning site. The maximum reported distance for a recaptured fish was approximately 24 km. Inter-annual and inter-monthly spawning site fidelity was shown for 20 of the 43 acoustically tagged individuals that included both males and females. Nine individual returned to the site repeatedly within the spawning season, oftentimes disappearing from the site for several months before returning. These patterns provide evidence that individual monthly aggregations are composed of a mixture of individuals that are moving to the site to spawn both for the first time and to repeat spawn within the reproductive year. Therefore, each aggregation does not represent the entire reproductive population for the species at that site. As such, estimates of population size (and changes therein) cannot rely solely on counts taken within an individual month, or sub-sample, of the reproductive season. In addition, a number of individuals demonstrated patterns of movement along the reef that suggests a common migratory pathway for many of the individuals spawning at the site. The combined results suggest a high level of fishing vulnerability for squaretail coralgrouper within the aggregation site and along migratory pathways where fish are concentrated during the reproductive season. Results further suggest that many of the individuals spawning at KMS are resident within a relatively small area (10-12 km linear distance from the site) proximate to the spawning site. Ripe males were taken from the KMS site beginning as many as 9 d prior to spawning, while gravid females were not taken more than 5 d before spawning. Within the tagging

program, the male-to-female capture ratio was 4:1. These findings demonstrate a disproportionate level of potential vulnerability among males at spawning sites temporally (or alternatively a disproportionately smaller number of available females), similar to that observed for other aggregating serranids. This disparity also may set the stage for selective fishing that may result in sperm limitation to reduce reproductive output. Also noteworthy is the relatively large catch (647 individuals, excluding those lost to sharks) taken from the spawning aggregation by two fishers over just 100 hrs of total fishing time (~ 3.8 fish hr^{-1} $fisher^{-1}$)—highlighting the ease of overfishing aggregations when fishing pressure is intense. These data highlight the need for improvements to the current management of the species in Pohnpei (and likely other aggregating serranids) that include a combined sale and catch ban on the species during the entire spawning season, with added protection provided by spawning aggregation site-based closures. Results also demonstrate that in order to fully protect reproductively active serranid during the spawning season, area protective measures must include migratory pathways. Findings highlight shortcomings in the existing marine protected area to fully protect reproductively active squaretail coralgrouper..

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Objectives

The project aims to investigate the effectiveness of an existing (fish) spawning aggregation site (FSA)-based MPA in protecting reproductively active fishes and provide recommendations from findings for enhancing design and the design of future FSA-based MPAs. The investigation is focusing on the squaretail coralgrouper, *Plectropomus areolatus* that co-occur at the Kehpara Marine Sanctuary (KMS) spawning aggregation site with the camouflage (*Epinephelus polyphekadion*) and brown-marbled grouper (*E. fuscoguttatus*).

Using conventional and acoustic tag-and-recapture techniques, we are evaluating the vulnerability of reproductively active grouper to the fishery by examining sex-specific patterns and distance of movement throughout the reproductive season that includes movement within, to, and away from sites and residency times and habitat usage at FSA. Preliminary analyses of spawning aggregations of this and other groupers suggest sex-specific differences in residency times and patterns of movement to aggregation sites. Evidence also suggests that spawning individuals utilize specific pathways to move to sites and that females move in schools to the FSA. These phenomena have the potential to enhance the vulnerability of reproductively active fish to exploitation and promote sex-specific selection of individuals by the fishery.

A secondary objective is to compare the relative contribution by individuals within a single aggregation month to the entire spawning season. In other words, during a 3 month-spawning period, do the same individuals aggregate each month or are aggregations a sub-set of the spawning population each month? This finding is critical to understanding the dynamics of the spawning population, its vulnerability to overfishing, and best methods in which to protect it.

Additional objectives are to (1) investigate the impacts on squaretail coralgrouper by the fishery during and between spawning months and (2) to evaluate sexual pattern for the species. Both objectives will rely on conventionally and radio-tagged fish. Tagged fish coming into the market will provide information on catch location and evidence that the individuals were taken outside the MPA. Gonad analysis will provide information on their reproductive state. Similarly, sexual pattern will be determined from macroscopic

gonad analysis of fish at tagging and following capture. Females subsequently captured as males provide indirect evidence of sex change in the species. Since hermaphroditic species may require special management and are affected differentially by fishing, an opportunistic investigation of sexual pattern is warranted.

These parameters will be used in conjunction with ongoing assessment and monitoring programs at the University of Guam Marine Laboratory to determine if changes are needed to existing MPA boundaries, to determine effective area and design for two pending sanctuaries (Ahnd Atoll) and to make proposed species-specific changes to existing management protocols.

Results

Acoustic tagging and receivers

A total of 20 male and 20 female squaretail coralgrouper were tagged at the Kehpara Marine Sanctuary using Vemco V16® acoustic tags in January and February 2005, respectively. One additional tag was deployed in April 2005, following the loss of an acoustic tag from one female and two additional males were tagged in February following the return of two tagged fish by the fishery in January. In association with the acoustic tagging component, seven Vemco VR2® receivers were deployed as proposed, including one receiver central to the FSA, two at (north and south) KMS boundaries, one at Kehpara Channel, 1-km from the aggregation center and three additional receivers at distances of 10-12 km from the aggregation center (Pehleng Channel, Nahlap Channel and between Dawahk and Pehleng Channels (Fig. 1). The receiver from Kehpara Channel has recently been moved to a lagoon location just inside the Kehpara Channel where aggregated (pre-spawn) individuals have been recently spotted (Fig. 1). Each receiver has been placed to meet the stated objectives of determining sex-specific resident times and pattern of movement for squaretail coralgrouper within and between spawning times.

Of the 42 tags deployed in January and February, signals were initially received from 31 individuals. Following the initial deployments, subsequent signals were received from 19 tags by at least one of the seven receivers providing information for pattern and distance of movement assessments. Of those tags picked up repeatedly (> 1 mo) by the receivers, 8 tags were from females, while the remaining 11 were males. Table 1 provides findings of the preliminary analysis of the tag returns (as receiver ping detections), while Table 2 gives location data for individuals.

Results from the past 15 months of acoustic monitoring suggest that each of five monthly (2 weeks mo^{-1}) squaretail coralgrouper spawning aggregations (FSA) within the reproductive period (January-May) is composed of a sub-population of the total adult population. In other words, varying proportions of the potential reproductive population participate in each monthly spawning bout; the entire adult population appears to never be present at the site during a single month. For example, of the 20 males acoustically

tagged in January 2005, only 30% (7 individuals) were present at the FSA site in February. This number was reduced to 25% (5 individuals) in March and 15% (3 individuals) in April and May. We assume that the individuals that never returned were likely lost to tag (since these were not returned to the program for tag rewards) mortality or to fishing. (The alternative is that these individuals spawned once within that reproductive year and may yet return in 2006.) Nonetheless, 7 individuals did show consistent return over a minimum of 3 months, while 2 fish returned repeatedly over 9 and 11 months, respectively, although not in consecutive months (Table 2). Meanwhile, actual abundance within the aggregation increased steadily between January and April[1]. Therefore, while some tagged individuals left the aggregation site and did not appear to participate in subsequent months, a substantial number of other spawners moved into the site to reproduce.

Preliminary results from both types of tagging support intra-seasonal and inter-annual site fidelity for some individuals and (potential) repeat spawning among a substantial percentage of males and females. At least 7 females were detected by one or more of the central of KMS boundary receivers between 2-5 months post-tagging and one individual returned in the subsequent year (Table 2). Two males (#10 and #21, Table 2) appeared to maintain a residency within the FSA area from January-September.

Acoustic data suggests that most individuals are reaching and leaving the FSA site via a northern route that takes them along the barrier reef and into the lagoon at one or more channel locations (Figure 1 and Tables 2 and 4). Only one individual was shown to move along the outer reef southward (*see* Table 2-Nahlap) and no individuals were found to actually use the small channel nearest to, and south of, the FSA site (Kehpara Channel).

[1] These impressions are taken from observations on snorkel during the tagging process and seasonal abundance profiles from underwater monitoring by the Conservation Society of Pohnpei 2000-2004 (*also see* Rhodes et al. 2005).

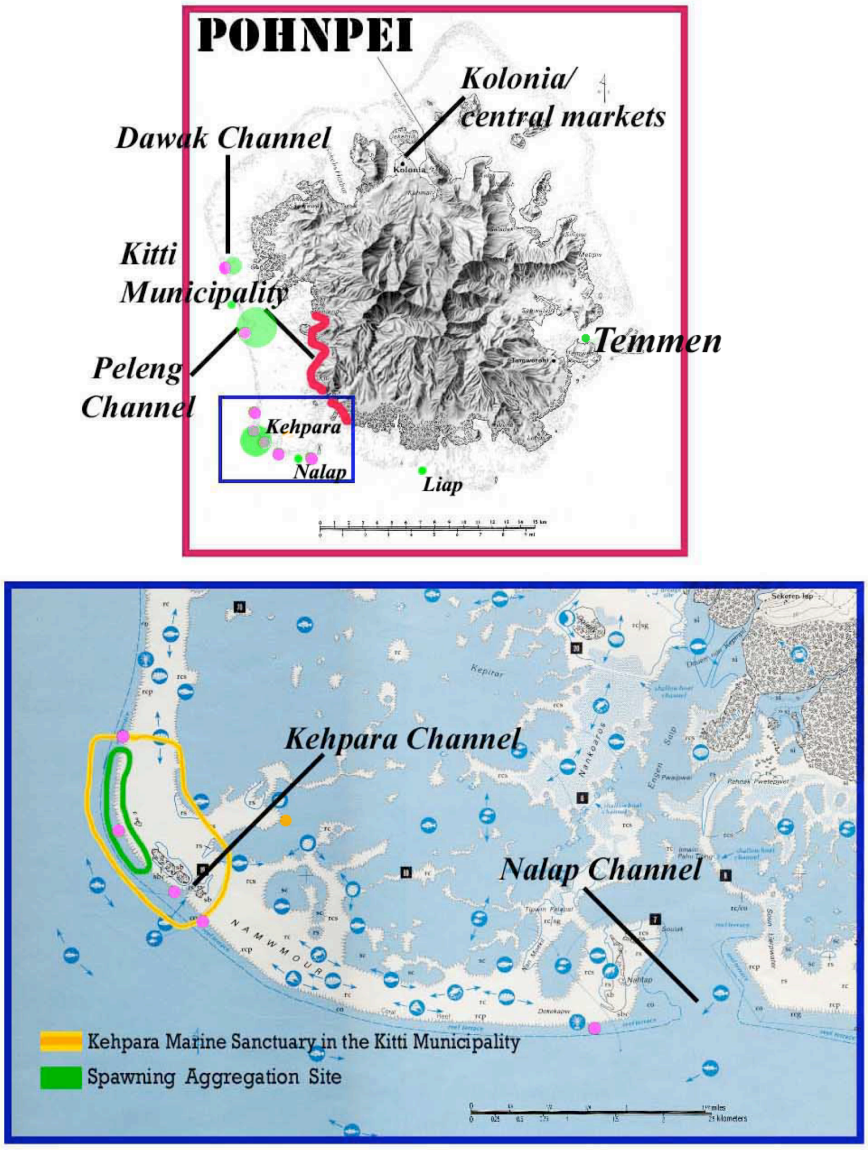

Figure 1: Top map shows the receiver locations (pink) and catch location for recaptured individuals (green). Dot sizes for recaptures are relative in size to the numbers of fish captured for each locale. The red line indicates the locations of most Kitti Municipality fisher communities, while the orange dot (lower) shows the position of the receiver moved from Kehpara Channel.

Individual	Sex	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb
1	M	X													
2	M		X	X	X	X									
3	M	X	X												
4	M	X	X												
5	M	X													
6	M	X													
7	M	X	X	X											
8	M	X													
9	M	X	X	X											
10	M	X	X	X	X	X	X	X	X	X	X		X	X	
11	M	X													
12	M	X													
13	M		X												
14	M	X	X												
15	M	X													
16	M	X	X	X	X										
17	M	X	X												
18	M	X	X	X											
19	M	X													
20	M	X													
21	M	X	X		X	X	X	X	X	X	X	X			
22	M	X													
23	F				X										
24	F		X	X											
25	F		X	X											
26	F		X												
27	F		X	X			X								
28	F		X												
29	F		X												
30	F		X												
31	F		X												
32	F		X												
33	F		X												
34	F		X	X											
35	F		X	X		X	X	X						X	X
36	F		X												
37	F		X												
38	F		X	X											
39	F		X												
40	F		X	X	X				X						
41	F		X	X											
42	F		X												
43	F		X												

Table 1: Summary table of preliminary results from the acoustic tagging program. The observed spawning period (local monitoring) is January-May. The individuals marked in yellow and green represent 2 fish returned by the fishery following initial tagging (January), with a second individual re-tagged with the same pinger in February. One individual (orange) was recovered by the fishery without the acoustic tag. A separate tag was deployed in a second individual (blue) in April.

		Month											
Tag	Sex	J	F	M	A	M	J	J	A	S	O	N	D	J
2250-A	M													
2250-B	M	C,N	C,N	C	C,D									
2251	M	C	C											
2252	M	C	C											
2253	M													
2254	M	C												
2255	M	C	C,N,P	C										
2256	M	C	C,N,P	C,N										
2257	M													
2258	M	C	C	C	C	C	C	C	C	C	C		C	C
2259	M	C,N												
2260-A	M													
2260-B	M													
2261	M	C,N,P	C											
2262	M													
2263	M	C	C,P	C,N, L	N									
2264	M	C	C											
2265	M	S,C,H	S,C	C										
2266	M													
2267	M	C												
2268	M	C	C		C	C	C	C	C,N	C	C	C,N,H,N		
2269	M	C,N												
2244	F				C,P,D									
2270	F		C,S											
2271	F		S	C,S,H										
2272	F													
2273	F		C,P	P			C							
2274	F													
2275	F		C											
2276	F				C									
2277	F													
2278	F													
2279	F		C											
2280	F		C	C,S										
2281	F		C	C,S		C	C	C						C
2282	F													
2283	F		C											
2284	F			S										
2285	F													
2286	F		C,N	N	N,D				N					
2287	F		C,N	C										
2288	F													
2289	F		C											

Table 2: Location information for the 43 acoustically tagged individuals collected over 15 months of the tagging program. Locations are as follows: C—central KMS receiver; N—north KMS boundary; S—south KMS boundary; P—Pehleng Channel; H—Kehpara Channel; L—Nahlap; D—north Pehleng Channel, between Pehleng and Dahwak.

Acoustic data also shows a difference in daily activity patterns, with males active between ~ 6 a.m.-6 p.m. and largely inactive during other times. Conversely, females remain activity during evening periods, possibly to feed and avoid males, which court them through the day and possibly reduce diurnal feeding opportunities (data not shown).

Additionally, acoustic data (supported by catch data, *below*) suggest the aggregation that formed during the initial month of the 'reproductive' season (January) was composed entirely, or nearly so, of males, such that the aggregation is not actually a spawning aggregation. Instead, the initial aggregation may promote or facilitate the

establishment of territories among males set to spawn in the subsequent month(s). Additional work is needed to confirm this finding and determine if all-male aggregations are common during the first month of the reproductive season.

Conventional tagging

Two local fishers, employing hook-and-line methods and using snorkel, collected a total of 647 individual squaretail coralgrouper between January and May 2005 in just over 100 hrs of fishing. At capture, fish were removed from the hook and placed in a 75-L container with MS-222 solution (0.75 g L^{-1}) for ~2-3 min prior to length, weight and sex determinations. Following Floy (and acoustic) and OTC tagging, fish were placed in an on-board 100-L recovery tank with fresh aerated seawater for 5-10 min prior to release. During initial recovery, all individuals were subject to airbladder deflation using a 20-gauge hypodermic needle. All releases took place over the reef flat in water 5-10 m depth to allow full recovery and minimize predation. Fishers fished an average of 3.1±0.9 hrs d^{-1}, with an average catch of 3.83 fish hr^{-1} (n=25 d^2). During the initial month of tagging several fish were observed on snorkel to monitor the recovery progress and duration. Within 5-10 minutes after release, all fish returned to normal activity, which included courtship and territorial chasing. Only one individual was observed to fall prey to sharks following release, although it is likely that other unobserved losses to predation occurred.

Of the 647 individuals tagged between 22 January and 21 May 2005, 129 individuals were females, 511were male and 7 were of undetermined sex (Table 3). (This sum includes those individuals with acoustic tags.) To date 59 tagged fish (9.1% of the total) have been recaptured either at the FSA or by the fishery (Table 4). All tagged individuals (n=20) recaptured by taggers (January-May) inside the KMS were male. Of the tags returned by the fishery, initial sex was as follows: one sexually unidentified, 8 females and 27 males. One individual was returned with an illegible tag and the sex remains unknown. No microscopic histological examinations have been undertaken to date for sexual identification or sexual pattern.

[2] CPUE findings represent a sub-sample of the total number of days fished and excludes catch and effort from January when data was not collected. Catch records also exclude fish lost to sharks.

As shown, 26.2% of the total catch by fishers were taken during the March-April sales ban period and 46.2% during the reproductive season[3], Those taken by taggers during the reproductive period represent an additional 33.9% of the total catch during the spawning season, demonstrating the high vulnerability experienced by fish during this period. The length frequency for all fish captured for tagging is shown in Figure 2.

Table 5 provides the results of the recapture locations and distances for both males and females and further suggests that individuals leaving the FSA following spawning predominantly take a northern route along the outer barrier reef[4] (*also see* Figure 1). Several of these individuals (*not detailed here*) were captured inside the lagoon, which suggests that individuals utilize the Pehleng and Dawahk channels to enter the lagoon for subsequent dispersal to home range or feeding sites. As shown, most individuals were captured within ~ 10-12 km of the FSA site—a finding that may also indicate the 'catchment area' for the FSA. A single individual was reportedly caught from Temmen Channel, approximately 27 km from the KMS (Fig. 1). The range of time (days) at liberty (DAL) ranged from 1-265 d, with an average time at liberty of 60 ± 71 d.

	All	***Male***	***Female***	***Unknown***
January	75	71	0	3
February	157	125	32	0
March	135	96	39	0
April	167	130	37	0
May	114	89	21	4
Totals	647	511	129	7

Table 3: Catch summary by month for conventional and acoustic tagging component.

[3] Fishers were permitted to provide tagged fish to the program during the sales ban period for grouper by Pohnpei State.

[4] Two acoustically tagged males and 1 acoustically tagged female were returned by the fishery; tags were removed and re-deployed in two other males and one other female in the month subsequent to capture

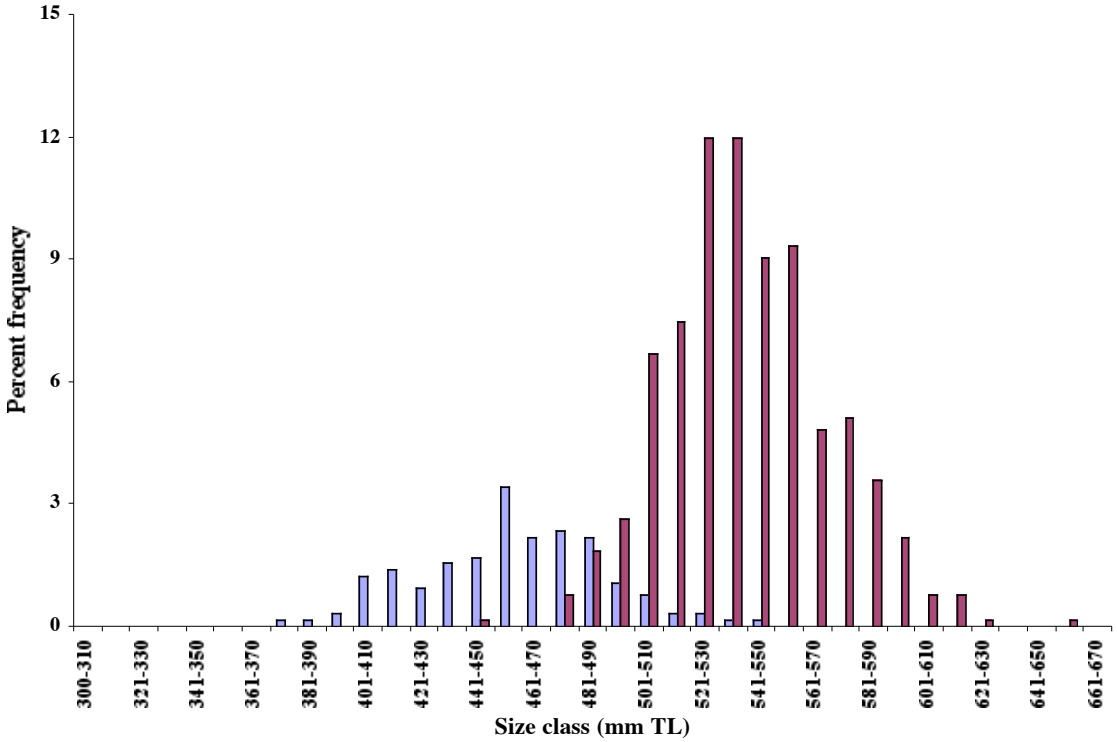

Figure 2: Size frequency of all squaretail coralgrouper captured during the tagging program. Females (n=129) ranged from 378-542 mm TL; males (n=511) ranged from 450-660 mm TL; fish that could not be sexed in the field (n=7) are not included.

Of the 59 fish recaptured (excluding the one male recaptured at the FSA twice), 75% of all females were taken within one month of initial tagging, with the maximum time at liberty recorded at 8 months (Table 6). In contrast, 66% of recaptured males were taken during the same month or month following tagging, demonstrating the temporal vulnerability of individuals to the fishery during or within the spawning season. One male remained at liberty for 11 months prior to recapture. Time at liberty did not correspond with distance of movement.

	J	F	M	A	M	J	J	A	S	O	N	D	J	F
Fishers (F)	1	5	7	3	8	3	0	0	1	1	6	0	2	2
Taggers (T)	0	2	6	5	7	0	0	0	0	0	0	0	0	0

Table 4: Results of the conventional tag-recapture component of the program. Numbers represent individual recaptures taken away from the site (fishers) and within the sanctuary (taggers). The shaded area represents the sales ban period. Months are abbreviated in the upper column.

SITE	*Sex*			*~ Distance from FSA (km)*
	M	*F*	*Unknown*	
KMS	20	0	0	0.0
Nalap	0	1	0	3.5
Liap	1	0	0	7.0
Peleng	18	7	0	8.0
Dawak	5	0	0	12.0
Penieu	1	0	0	12.0
Temmen	0	0	1	27.0
Unknown	3	0	2	***
Totals	48	8	3	

Table 5: Summary table of site locations for recaptured fish by sex. Sites listings are relative to the location and distance away from and on either side of the Kehpara FSA. M=male; F=female.

	Months at liberty												
	0	1	2	3	4	5	6	7	8	9	10	11	12
Male	4	21	8	5	1	0	5	1	0	2	0	1	0
Female	0	6	0	1	0	0	0	0	1	0	0	0	0
% total M	*8*	*44*	*17*	*10*	*2*	*0*	*10*	*2*	*0*	*4*	*0*	*2*	*0*
% total F	*0*	*75*	*0*	*13*	*0*	*0*	*0*	*0*	*13*	*0*	*0*	*0*	*0*

Table 6: Summary table of times at liberty prior to recapture. The lower two rows show the percentages of the totals, by sex, for each month from tagging.

Age, growth and sexual pattern

Of the 39 fish reported as recaptures. 29 tags were returned by the fishery with the fish, allowing the removal of otoliths and gonads for subsequent age, growth and reproductive life history assessments. OTC tagging provided 29 otoliths for validation of age and growth assessment. These otoliths will be assessed in 2007, along with additional monthly collections taken from market specimens between January and December 2006. Similarly, gonads will be assessed following the completion of monthly sample collections in 2006 through the 2006 NOAA-funded Pohnpei fish market survey.

Genetic sampling

Of the 648 fish captured at the Sanctuary, all individuals were sampled for subsequent genetic analysis. Sample sizes reflect those presented in Table 2. Fin clips were taken for each individual and stored in NetStar® biological preservative. Fin clips have been used successfully by co-PI Rhodes to assess population genetic structure of camouflage grouper across the central and western Pacific (Rhodes et al. 2002).

Program announcement

The program was continually (twice daily-2005; bi-weekly 2006) announced to the general public using radio media until March 2006, with print media supplementing radio announcements during the initial tagging months. Fishers were also directly informed of the program's continuation during the 2006 NOAA-funded Pohnpei fish market survey. Local AM radio produced the announcement in both English and Pohnpeian and acknowledges support and participation by NOAA, the University of Guam, Conservation Society of Pohnpei (CSP) and Department of Marine Resource Development. Translations were provided by CSP.

Local involvement

Throughout the program three local state, non-governmental and academic organizations participated in the program. The Conservation Society of Pohnpei supported program efforts by collecting re-captured fish and information on fishers, location and catch method for tagged fish returned through the fishery. The Department of Marine Resource Development (DMRD) provided additional boat support (one boat) and two state conservation officers who worked with co-PI Rhodes during tagging efforts and receiver maintenance. DMRD also provided daily transportation during program activities for scuba tank, fuel, personnel and supply movement between Kolonia and the dock. The College of Micronesia (COM) provided three interns to assist and learn techniques and

concepts. The COM internship rewarded three class credits through student participation in the program. Students are supervised by Mr. Brian Lynch of the Education Department at COM. Program components, conducted by co-PI Rhodes have included:

- "Introduction to Fisheries Management and Conservation of Reef Fishes using Tag-and-Recapture Technique"
- "Age and Growth in Fishes: An introduction"
- "Introduction to Reproductive Development and Spawning in Tropical Marine Reef Fishes"

All academic components included classroom presentations and on-site participation in each of the three months of the project. In addition to COM participation, Mr. Peter Dixon (University of Guam, Master's program) participated in tagging activities in January and March 2005.

Future Goals and Timeline

The tag-recapture reward scheme is continuing until the end of May 2006 to allow a minimum of 1-year opportunity for each tagged individual to be at liberty and be captured by the fishery. Although the AM radio program announcements have discontinued, direct daily fisher contact are possible through the 2006 NOAA-funded Pohnpei fish market survey. Similarly, acoustic receivers remain active, with a final download scheduled for the end of May 2006. This proposed schedule allows for data collection over two complete reproductive seasons.

Final analysis will be conducted following conclusion of the tagging program (May 2006) and be updated as tags are recovered. Recommendations to the Pohnpei State Legislature were made in March 2005 and will again be made in May 2006. Findings from the tagging program will be combined with those the current fish market survey and the 2005 CSP-sponsored reef fish and coral REA (rapid ecological assessment) findings

to provide a comprehensive assessment and recommendations to management needs in Pohnpei. The preliminary findings will be presented at the 2006 American Society of Ichthyologists and Herpetologists (ASIH) annual meeting in New Orleans. Findings are currently being analyzed in manuscript format for submission this summer. We anticipate no difficulties in meeting all proposed objectives at this time.

Preliminary Conclusions

The data suggests that each of the spawning aggregations that form for squaretail coralgrouper between January and May in Pohnpei is composed of a sub-set of the adult (reproductive) population. Further, the composition of each aggregation is varied, with some individuals utilizing the site for reproduction for the first time that year, while (what appears to be) a smaller proportion are individuals returning from a previous month(s) to spawn again. To reach the FSA site, individuals appear to migrate predominantly from the area north of the site (e.g. Dawahk and Pehleng areas, *Figure 1*) and move along the outer barrier reef to do so. In contrast, findings suggest that fewer individuals reach the site from locations south of the FSA site and no fish have been shown to utilize Kehpara Channel to reach the outer reef from the lagoon (although we are still investigating this possibility). This is in contrast to anecdotal accounts from recent years reporting that hundreds of individuals passed through the channel from the barrier reef to the lagoon following spawning. During these periods, individuals were netted in large numbers. These past reports, combined with our current findings, suggest that another separate FSA likely existed previously within the area, but was fished out in recent years by net fishing[5]. However, recent observations inside the lagoon (just inside and east of the channel) show concentrations of squaretail coralgrouper, while camouflage and brown-marbled grouper have been observed in the channel over the past two years just prior to aggregation periods. No squaretail coralgrouper have been

[5] Alternatively, post-spawn individuals currently utilize a different migratory pathway than that of the recent past.

observed, however, within the channel nor have signals been detected by the receiver placed inside the channel.

Vulnerability assessments from fishing at both the FSA site during tagging and from recaptured fish show that individuals are highly vulnerable to both hook and line (tagging) and spearfishing (fishery) within the reproductive period. Results also strongly suggest that the sales ban period alone—that allows subsistence catch—is ineffective in reducing the potential for overfishing, since a large proportion of fish appear to be taken along migratory pathways and at feeding sites within this period. The Kehpara Marine Sanctuary, in contrast, appears to reduce overfishing. Indeed, more than 34% of tagged fish recaptured came from fishing within the FSA (by taggers). Without this area protective measure, these and other spawning individuals would have become targets of the fishery. However, the relatively high number of tagged fish supports the need for inclusion of migratory pathways into the KMS. Even more substantial is the fact that only two fishers participated in the tagging program for a mean daily fishing period of 3.1±0.9 hrs d^{-1} and a total of 647 fish in a single reproductive season, whereas open access would have allowed a substantially higher number of fishers into the area to fish over a longer time period. For example, past observations of fishing on the adjacent camouflage grouper FSA revealed that thousands of individuals representing 25% or greater of the total FSA population can be taken from the FSA over a very brief (~7 d) period (Rhodes 1999).

While these findings answer some important questions concerning fish movement around spawning times, the project also highlights the need for additional information on 'catchment areas' and additional FSA sites and fisher vulnerability. If this data is correct, FSA are comprised of highly localized adult populations (within 10-12 km linear distance of the FSA), in contrast to fishes from throughout the total reef and lagoon area of Pohnpei. Therefore, not only is likely that squaretail coralgrouper FSA may be found at somewhat regular intervals along the reef, it also appears likely that the loss of one of these FSA will affect local populations, fishing success and inflict additional pressure on other target species. Therefore, the identification and area protection of other FSA is

critical, as is the need to improve management through complete area and temporal fisheries closures within reproductive periods.

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